

## COMPRESSOR HAVING AN ADJUSTABLE DIFFUSER WALL AND METHOD THEREFOR

### FIELD OF THE INVENTION

The present invention relates generally to compressors and, more particularly, to a compressor with an adjustable diffuser for adjusting the configuration of a passage defined by the diffuser.

### BACKGROUND OF THE INVENTION

Compressors, such as those used in turbochargers, typically include a compressor wheel that is rotatably mounted in a housing and that defines blades extending radially outward in proximity to an inner surface of the housing. The housing defines an inlet for receiving air or other gas, and an annular diffuser extends circumferentially around the housing to receive the air therefrom. A volute, disposed radially outward from the diffuser, is structured to receive the air from the diffuser. During operation, the air is compressed by the rotation of the blades of the compressor wheel and delivered radially outward through the diffuser to the volute. The compressor wheel is normally rotated at a high speed, such that the air is moved at a high velocity to the diffuser, which then slows the air and increases the static pressure of the air. In the volute, which provides a relatively large volume compared to the diffuser, the velocity of the air is further reduced and the static pressure of the air is also increased.

Preferably, the compressor can be used over a range of operating pressures. For example, a compressor used in a turbocharger may be operated over a range of speeds and pressures depending on the operating mode of an engine with which the turbocharger is used. However, the operating range of the compressor and, hence, the turbocharger, is typically limited by two phenomena

referred to as surging and choking. Surging refers to a condition in which a low volumetric flow of air through the compressor and a high pressure difference between the inlet and the outlet of the compressor result in "stalling" of the compressor and a periodic reversing flow from the outlet to the inlet. Choking  
5 refers to a condition in which the velocity of air inside the inducer portion of the compressor reaches sonic velocity and cannot be increased further by the compressor.

Some conventional compressors include a surface in the diffuser that can be moved relative to an opposed fixed surface in the diffuser, thereby varying the  
10 capacity of the compressor and stabilizing the operation of the compressor to avoid surging. The movable surface can be moved by a drive mechanism as required for stabilizing the flow of the gas through the compressor. However, such drive mechanisms add to the complexity of the compressor, thereby increasing the costs associated with manufacturing and operating the device.

15 Thus, there exists a continued need for an improved compressor and diffuser therefor, such as can be used with turbochargers and other devices requiring the compression of air or other fluids. The compressor should be capable of being operated over a range of pressures and/or speeds without stalling or choking.

## 20 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a section view illustrating a compressor having an adjustable  
25 diffuser according to one embodiment of the present invention;

Figure 2 is a partial section view illustrating the compressor of Figure 1 with the diffuser wall shown in an open position;

Figure 3 is a partial section view illustrating the compressor of Figure 1 with the diffuser wall shown in a closed position;

30 Figure 4 is partial section view illustrating a diffuser wall according to another embodiment of the present invention, shown in an open position;

Figure 5 is a partial section view illustrating the diffuser wall of Figure 4, shown in a closed position;

Figure 6 is a graph illustrating the operating ranges of a compressor as a function of pressure, speed, and air flow according to one embodiment of the present invention;

Figure 7 is partial section view illustrating the adjustable diffuser wall of the compressor of Figure 1 with a control valve according to one embodiment of the present invention, the control valve being shown in a first position; and

Figure 8 is a partial section view illustrating the adjustable diffuser wall and control valve of Figure 7 with the control valve in a second position.

### DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

Referring to Figure 1, there is shown a compressor 10 with an adjustable diffuser 30 according to one embodiment of the present invention. The compressor 10 can be used for delivering and compressing a variety of fluids, and the compressor 10 can be used in conjunction with various devices and applications. For example, the compressor 10 can be coupled to a turbine of a turbocharger for a combustion engine and used to provide compressed air for combustion in the engine.

As shown in Figure 1, the compressor 10 includes a compressor wheel 12 disposed in a compressor wheel housing 14. The wheel 12 is rotatably mounted in the housing 14 on a shaft 16 that extends from the housing 14, e.g., through a center housing and to a turbine of a turbocharger (not shown). Thus, the wheel 12 is configured to be rotated in the housing 14 by the shaft 16. A plurality of blades 18 extend radially outward from the compressor wheel 12, and the blades 18

extend proximate to a contoured inner surface 20 of the housing 14 so that the compressor wheel 12 can be used to deliver air through the housing 14. More particularly, the compressor wheel 12 is configured to draw air into the housing 14 through an inlet 24 and deliver the air to a body of the diffuser 30 and a volute 26 of the compressor 10. The compressed air can be delivered from the volute 26 through an outlet (not shown).

The diffuser 30 extends circumferentially around the compressor wheel housing 14 and defines a fluid passage 32 connected to the housing 14. The volute 26 extends circumferentially around the diffuser 30 and is configured to receive the air from the housing 14 via the diffuser 30. All or part of the diffuser 30 and volute 26 can be formed integrally with the compressor wheel housing 14, and the diffuser 30 can correspond in size and shape to a center housing of a turbocharger or another device for connection thereto. For example, the housing 14 can include a backplate 15 that is bolted or otherwise attached to the rest of the housing 14, and the backplate 15 can be connected to the center housing or other device.

The passage 32 of the diffuser 30 is defined by a stationary inner surface 34 and an adjustable diffuser wall 36 disposed in the diffuser 30. The adjustable diffuser wall 36 extends circumferentially in the diffuser 30, i.e., in a partial or complete annular configuration. As shown in Figure 2, a first side 38 of the diffuser wall 36 is directed toward the inner surface 34 of the diffuser 30. A second side 39 of the diffuser wall 36, which is opposite the first side 38, is actuated by a control fluid provided through a fluid port 40. For example, the adjustable diffuser wall 36 can be disposed in an annular recess 42 or other space provided in the diffuser 30 opposite the inner surface 34 and configured to be adjusted out of the recess 42 toward the inner surface 34. Thus, by adjusting the diffuser wall 36 relative to the inner surface 34 of the diffuser 30, a gap defining the passage 32 between the diffuser wall 36 and the inner surface 34 can be changed.

Figures 2 and 3 illustrate the adjustment of the diffuser wall 36 according to one embodiment of the present invention. The adjustable diffuser wall 36 is connected to a first side 46 of a diaphragm 44, which can be formed of a

deformable material such as an elastomeric sheet. For example, the adjustable diffuser wall 36 can be connected to the diaphragm 44 by rivets 49 or other connectors. The diaphragm 44 extends circumferentially in the recess 42, and radially inner and outer peripheral portions 50, 52 of the diaphragm 44 can be  
5 connected to radially inner and outer sides 54, 56 of the recess 42. A second side 48 of the diaphragm 44, opposite the first side 46, is therefore in fluid communication with the fluid port 40.

The fluid port 40 is configured to receive the control fluid such that the control fluid is delivered to the recess 42 and provides a force on the diaphragm  
10 44 and, hence, the adjustable diffuser wall 36, in the direction of the inner surface 34 of the diffuser 30. If the pressure of the control fluid in the recess 42 is greater than the pressure of the gas in the passage 32 of the diffuser 30, the adjustable diffuser wall 36 is urged toward the inner surface 34, thereby reducing the size of the gap defining the passage 32 as shown in Figure 3. Alternatively, if the  
15 pressure of the control fluid in the recess 42 is less than the pressure of the gas in the passage 32, the adjustable diffuser wall 36 is urged away from the inner surface 34, i.e., into the recess 42, thereby increasing the size of the gap defining the passage 32 as shown in Figure 2. One or more projections or stops 58, 59 can be provided on the adjustable diffuser wall 36 and/or the diaphragm 44 to limit the  
20 motion of the wall 36. That is, when the diffuser wall 36 is urged toward the inner surface 34 (Figure 3), first stops 58 on the diffuser wall 36 can be pushed into contact with the inner surface 34 so that the diffuser wall 36 is adjusted to a first, or closed, position, in which a reduced flow of the gas can be maintained through the passage 32 to the volute 26. Similarly, when the diffuser wall 36 is urged  
25 away from the inner surface 34 (Figure 2), second stops 59 on the diffuser wall 36 can be pushed into contact with the inner surface 34 so that the diffuser wall 36 is adjusted to a second, or open, position.

While the radially inner and outer peripheral portions 50, 52 of the diaphragm 44 are shown to be connected to the diffuser 30 in Figures 2 and 3, it is  
30 appreciated that the diffuser wall 36 can alternatively be supported in various other configurations. For example, as shown in Figures 4 and 5, the outer peripheral portion 52 of the diaphragm 44 can be connected to the radially outer

side 56 of the recess 42, and the inner peripheral area 50 can be connected to a first sealing member 60. The first sealing member 60 corresponds to a second sealing member 62 provided at the radially inner side 54 of the recess 42 so that the first and second sealing members 60, 62 form a seal therebetween as the first  
5 sealing member 60 is adjusted with the adjustable diffuser wall 36 in sliding contact with the second sealing member 62. Thus, the adjustable diffuser wall 36 can be adjusted between a first, or closed, position (Figure 5) and a second, or open, position (Figure 4). In the open position, the first sealing member 60 can be adjusted against the recess 42 as shown in Figure 4 so that the sealing member 60  
10 acts as a stop to limit the adjustment of the diffuser wall 36.

By adjusting the size of the gap defining the passage 32 in the diffuser 30, the cross-sectional size of the passage 32 can be increased or decreased. Thus, the adjustable diffuser wall 36 provides an adjustable cross-sectional flow area for the passage 32, as can be appropriate for different air mass flow rates through the  
15 diffuser 30. Advantageously, the operating range of the compressor 10 can be extended by adjusting the size of the passage 32. For example, at times when the compressor 10 is subject to stalling due to a low volumetric flow of air through the compressor 10, the adjustable diffuser wall 36 can be adjusted to the closed position to decrease the required flow rate at which the compressor 10 will stall.  
20 Alternatively, when the compressor 10 is subject to a higher mass flow rate of the air entering the compressor 10 at a high velocity, the adjustable diffuser wall 36 can be adjusted to the open position to decrease the surface friction of air through the diffuser 30 and, hence, increase the efficiency of the compressor 10. In other embodiments of the present invention, the diffuser 30 can be adjusted at different  
25 times, according to other operational parameters, and/or to achieve other operational results.

Figure 6 is a graph illustrating the operating ranges 90a, 90b of a compressor according to one embodiment of the present invention. As illustrated, the extent of each operating range 90a, 90b of the compressor 10 is dependent on  
30 the mode in which the compressor 10 is operating, i.e., with the diffuser 30 closed or open. The left-most edge 92a, 92b of each operating range 90a, 90b indicates the operating points at which the compressor 10 is subject to stalling. The

rightmost edge 94a, 94b of each operating range 90a, 90b indicates the operating points at which the compressor 10 is subject to choking. Thus, the area within each operating range 90a, 90b indicates the operating conditions under which the compressor 10 can be operated with little risk of stalling or choking. In addition, the operating efficiency of the compressor 10 generally increases near the center of each operating range 90a, 90b as indicated by the percent efficiency values shown on the graph. Curved lines extending across each operating range indicate the operating speed of the compressor 10, between 80,000 and 180,000 revolutions per minute (RPM) in the illustrated embodiment.

The operating ranges 90a, 90b for the two modes of operation are not co-extensive. More particularly, the range 90a of the compressor 10 in the first mode of operation, in which the diffuser 30 is closed, generally extends further to the left in the graph. The range 90b of the compressor 10 in the second mode of operation, in which the diffuser 30 is open, extends further to the right in the graph. For example, at point 100 in the first operating range 90a, a pressure ratio of the compressor 10, i.e., the pressure exiting the volute 26 divided by the pressure of the atmosphere, is equal to about 1.8, and the compressor 10 is rotating at a speed of about 120,000 RPM, resulting in a flow of air through the compressor 10 at a first rate. Point 100 is within the operating range 90a of the compressor 10 for the first mode of operation (diffuser 30 closed) but is outside the operating range 90b for the second mode of operation (diffuser 30 open). Alternatively, at point 102 of the second operating range 90b, the pressure ratio is 1.8 and the compressor 10 is rotating at a speed of about 160,000 RPM. Point 102 is within the operating range 90b of the compressor 10 for the second mode of operation (diffuser 30 open) but is outside the operating range 90a for the first mode of operation (diffuser 30 closed). Thus, the compressor 10 can be operated in an extended, or combined, operating range by closing the diffuser 30 when the compressor 10 is operating at low air flow rates and opening the diffuser 30 when the compressor 10 is operating at high air flow rates. Within those ranges where the operating ranges overlap 90a, 90b, i.e., where the compressor 10 can be operated with the diffuser 30 open or closed, the diffuser 30 can be adjusted to the

mode for which the operating efficiency is higher for the current operating conditions.

The control fluid can be provided through a selection valve 70 configured to adjust the pressure thereof, as illustrated in Figures 7 and 8. For example, the  
5 selection valve 70 can be configured to selectively provide the pressurized gas from one of two fluid sources 72, 74. The first fluid source 72 can be a vent to an ambient source, e.g., the ambient air in the operating environment of the compressor 10, which provides atmospheric pressure. The second fluid source 74 can be the volute 26, which is typically pressurized with air having a static  
10 pressure higher than the pressure in the diffuser 30. Thus, in a first mode of operation (Figure 8), the volute pressure is provided through the selection valve 70, and the diffuser wall 36 is urged to the first position, thereby minimizing the cross-sectional flow area of the diffuser 30. In a second mode of operation (Figure 7), the air at atmospheric pressure is provided through the selection valve  
15 70, and the diffuser wall 36 is urged to the second position, thereby maximizing the cross-sectional flow area of the diffuser 30. The selection valve 70 can be controlled by a mechanical or electrical controller (not shown) that senses operating parameters of the compressor 10 and adjusts the valve 70 accordingly. Such operating parameters can include the pressure or velocity of the air in  
20 different portions of the compressor 10, the speed of the wheel 12, and operating parameters of devices external to the compressor 10. For example, according to one embodiment of the present invention, the diffuser 30 is used in conjunction with a turbocharger for a combustion engine, which operates through a range of rotation speeds, the speed of the engine generally being correlated to the air flow  
25 rate through the compressor 10. The diffuser 30 can be closed at low engine speeds, such as below about 2000 RPM, and opened at higher engine speeds. Thus, the operating range of the compressor 10 is extended such that the turbocharger can be used to provide torque at low engine speeds. Further, the efficiency of the compressor 10 can be improved by selectively operating the  
30 compressor 10 in the mode that is most efficient for any given operating conditions.



It is appreciated that different control fluids from alternative sources can be provided for adjusting the diffuser wall 36. For example, pressurized air or other gases can be provided from other portions of the compressor 10 or from other components of a turbocharger or engine operated in conjunction with the compressor 10. Further, the control fluid can be an intermediate fluid in communication with the fluids from the fluid sources 72, 74, i.e., such that the fluids from the fluid sources 72, 74 provide pressure to the diffuser wall 36 via the control fluid without the fluids from the fluid sources being delivered directly to the diffuser wall 36.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.